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A Systematic Review and Meta-Analysis of Survivorship and Wear Rates of Metal and Ceramic Heads articulating with Polyethylene Liners in Total Hip Arthroplasty

Short Title: Survivorship and Wear Rates of Metal and Ceramic heads on polyethylene

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Abstract (250)
Background

The major joint registries report better survivorship for ceramic on polyethylene over metal on polyethylene bearings in total hip arthoplasty and it is generally accepted that this is due to a lower polyethylene wear rate. We used evidence synthesis to compare survivorship, polyethylene wear rates and metal ion levels for metal-on-polyethylene (MoP) and ceramic-on-polyethylene (CoP) bearings. If wear rates are not dissimilar in vivo this difference in revision rate may have another cause. Modular junctions are a potential source of corrosion and it is postulated that this may result in higher revision rates.

Methods

We performed a systematic review and meta-analysis comparing the survivorship of MoP and CoP bearings. Odds ratio (95% CI) of revision was calculated. Mean difference (MD) and 95% confidence intervals (CI) were used to compare secondary outcomes of polyethylene wear and metal ion levels. Meta-analysis was performed with a Mantel-Haenszel Random-Effects Model.

Results

Six randomised controlled trials were included. There was no statistically significant difference between MoP and CoP revision rate (OR: 1.04, 95% CI: 0.37 to 2.90, I^2 = 0%, p=0.94), linear bearing wear (MD: 0.00mm, 95% CI: -0.05 to 0.05,I^2=98%, p=0.90), nor volumetric bearing wear (MD: 33.57 mm^3, 95% CI: -215.56 to 282.70,I^2=98%, p=0.79). No studies evaluated metal ion levels.

Conclusions

We found no evidence of a difference in revision rates nor linear and volumetric wear between MoP and CoP bearings in the randomised controlled trials currently available. Our

study therefore does not advocate the additional cost associated with the use of ceramic heads in combination with polyethylene bearings in order to minimise revision rates. This contrasts the findings of in-vitro studies and the major joint registries.

Keywords: Total hip arthroplasty; Reoperation; Prosthesis failure; Corrosion; Implant bearings

Introduction

The National Joint Registry of England, Wales, Northern Ireland and the Isle of Man (NJR) demonstrates a higher revision rate for MoP versus CoP bearings in the most commonly implanted prostheses in the UK as seen in table 1. The NJR also shows an increasing use of ceramic on polyethylene (CoP) compared to metal on polyethylene (MoP) [1]. If there is an in vivo decreased wear rate in CoP over MoP then this would help to justify the higher cost associated with this trend in bearing choice, particularly in the younger population where decreased polyethylene wear and resultant osteolysis is arguably more important in helping to reduce the risk of long-term revision.

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Several studies have demonstrated decreased in vitro wear with the use of CoP over MoP bearings [2-5]. This is thought to be due to ceramic heads having better wettability, decreased surface roughness and increased hardness and consequent increased resistance to scratching [6,7]. However doubt remains over the transferability of these results in-vivo, with the choice of lubricant and its serum protein concentration used for in-vitro studies having a dramatic impact on the amount of wear observed [8,9].

There is no high quality evidence comparing the wear rates of the two bearing combinations in vivo, with no large randomised controlled trials having been conducted. We therefore sought to discover whether the difference in revision rate between the two bearing combinations was due to differences in wear rate or some other phenomenon such as corrosion at the head neck taper [10], which may be reduced by the use of ceramic heads [11].

We performed a systematic review and meta-analysis of the outcomes of primary modular THA performed with MoP or CoP bearing couples to establish if there was:

(i) a difference in overall revision rates between the bearing options;

(ii) a difference in surrogate measures of trunnion corrosion such as serum metal ion levels;

(iii) a difference in linear and volumetric bearing wear rates.

Materials and Methods

Data sources and search strategy

Our review was conducted in accordance with the PRISMA and MOOSE guidelines (see appendix 2. Two independent reviewers (N.H. and T.G.F) screened MEDLINE, EMBASE, CINALH, the Cochrane Database for Systematic Reviews, and the Compendex of Engineering from inception to February 2017 for comparative or randomized studies in this topic. A language restriction to English was applied; however, both published and unpublished studies were sought. The search was comprised of several key words and Medical Subject Headings, these included: total hip arthroplasty, ceramic-on-polyethylene, metal-on-polyethylene, metal-on-metal, ceramic-on-ceramic, head-neck interface, adverse reaction to metal debris, corrosion, and implant failure. The search strategy was initially piloted with MEDLINE prior to being applied to the other databases. In addition to MoP and CoP bearings, we also included other bearing systems in the search to ensure comprehensiveness and that no relevant article was missed. Additionally, the bibliographies of all included articles were also examined by the independent reviewers. Finally, potential articles were also identified using the related article feature on PubMed. The full search criteria used can be seen in Appendix A.

Eligibility criteria

We included studies comprising of randomly allocated adult (>18 years of age) patients undergoing THA to either a MoP or CoP bearing combination. We excluded studies: (i) where patients were not randomly allocated to treatment group, (ii) studies that did not include both interventions of interest (MoP and CoP bearing combination). If it was not clear whether patients were randomly allocated to intervention group, attempts were made to contact the corresponding author for clarification. See figure 1.

Data extraction and quality assessment

Three independent reviewers (O.G., N.H. and T.G.F.) assessed each potential article for eligibility based on the defined inclusion/exclusion criteria and any discrepancies regarding eligibility of an article was discussed, and consensus reached with a fourth author (A.A.). Data extraction was independently carried out by two reviewers (N.H. and T.G.F.) to prevent error and ensure accuracy. The extraction form contained several items that were specific to both study methodology, and the primary and secondary outcomes assessed. In cases of discrepancy, both reviewers discussed until a consensus was reached. For multiple publications involving the same study, the most comprehensive study was used. We attempted to contact study investigators to provide any missing information. The methodological quality of the included randomized trials was assessed using the Cochrane Tool for assessment of risk of bias. Two independent reviewers (N.H. and T.G.F.) independently assessed the studies using questions which related to randomization, blinding, level of incomplete data reporting and selective outcome reporting. Due to the fact that surgical procedures were being performed and the outcomes of interest, blinding of the participants was not deemed to be relevant and this question was excluded from the assessment. An unweighted kappa (κ) was calculated to assess the agreement between the two independent reviewers.

Statistical analysis

Odds ratio (OR) with a 95% confidence interval (CI) was calculated for the total number of revisions. If follow-up times were reported, the data was further stratified; otherwise, the data was pooled irrespective of follow-up time. The secondary outcomes analysed were metal

ion levels and bearing wear (to determine if differences in wear between the bearing couples could account for any differences in observed revision rates). The studies included in this review used varying methods for the quantification of wear. A mean difference (MD) with a 95% CI was calculated when the same overall parameter was being measured. In situations where the measurement of a variable differed between studies, a standardized mean difference (SMD) with a 95% CI was calculated as a way to control for variation. Range values were converted into standard deviation (SD) using the equation SD=[max-min]/4 in accordance with Hozo et al. [12].

Heterogeneity was evaluated through analysis of the I^2 statistic. The threshold for conducting subgroup analyses was an I^2>40%. As suggested by the Cochrane Handbook for Systematic Reviews, an I^2 greater than this value suggests that heterogeneity may be present[13]. If heterogeneity was present, it was explored on the basis of overall study quality and femoral head size.

In situations where data could be pooled, a meta-analysis was performed using the Mantel-Haenszel Random-Effects Model since there was expected heterogeneity between the included studies. In cases when data could not be pooled, a summary and a graphical representation of the overall effects were created.

Results

Study identification and selection

Screening identified a total of 1996 potentially eligible articles. After elimination of duplicates, a total of 1629 articles were assessed. The majority were excluded as they were non-randomized in nature, biomechanical studies, *in vitro* studies, or did not include the comparison of interest (figure 1). The full text of 11 articles were assessed, four were excluded as allocation was not randomised and one was excluded as detailed inspection revealed it did not contain the comparison group of interest. As such, a total of six randomized studies were included in this systematic review and meta-analysis. The raw agreement between reviewers was found to be 0.87 and the un-weighted κ was 0.74, which represents excellent agreement.

Study characteristics and study quality

A detailed overview of each of the included studies can be found in Table 2. Overall, there were a combined total of 693 patients (854 hips). The mean age of the patients ranged from 61 to 69 years old. Follow up was relatively short for all studies, with a range from 2-8 years. Six of the studies were randomized controlled trials. Three studies exclusively utilized a 28mm head [14-16], one study exclusively used a 26mm head [17] and one study exclusively used a 22mm head [18]. One study [19] randomized patients undergoing bilateral simultaneous THA to MoP 28mm, CoP 28mm, MoP 22mm, or CoP 22mm heads on each side. The hips for each patient were treated as independent events for the consideration of results from this study. The primary outcome of revision rate was reported by five studies [14-17,19]. Linear wear and volumetric wear [15,17,19], although Ise et al. measured volumetric wear rate per year. The secondary outcome of corrosion as assessed by the measurement of metal ion levels was not assessed by any of the studies.

For the assessment of the risk of bias, the raw agreement between the reviewers was 83% and the un-weighted κ was calculated to be 0.81, which represents excellent agreement. One study reported randomizing patients on the basis of rolling a dice which, which was suggestive of a high risk of bias [17]. All six studies had good follow-up rates and had little incomplete data (Figure 2).

Revision rates

A total of five studies reported revision for MoP in comparison to CoP (542 patients) [14-17,19]. A full list of the reported revisions can be seen in Table 3. Overall, the odds ratio of having a revision for any cause was not found to significantly different between patients that received MoP and those that received CoP (OR: 1.04, 95% CI: 0.37 to 2.90, I^2 = 0%, p=0.94) (Figure 3).

Metal ion levels

None of the included studies evaluated metal ion levels.

Linear wear

Linear wear rate per year was assessed by five studies (406 hips) [15-19]. Two studies used 28mm heads only [15,16], one study used 26mm heads [17], one study used 22mm heads [18] and one study used both 28 and 22mm heads [19]. The linear wear rate per year was not significantly different between the two bearing surfaces (MD: 0.00mm, 95% CI: -0.05-0.05,I^2=98%, p=0.90) (Figure 4). Subgroup analysis was performed on the basis of femoral head size, which included 22mm, 26mm, and 28mm. No significant differences were found between the subgroups with regard to linear wear rate per year as the size of the femoral

head increased (X^2 = 0.97, I^2=0%, p=0.61) (Figure 5). However, a non-significant trend towards greater linear wear rates per year with progressively larger femoral head sizes was noted.

Volumetric wear

Four studies evaluated volumetric wear; however, one study evaluated volumetric wear rates per year and was not included in the statistical analysis [18]. This study, using 22mm heads, found no significant difference between CoP and MoP in regards to volumetric wear rate per year (p<0.05) [18]. Therefore, three studies (182 patients/306 hips) were used in the statistical analysis of volumetric wear [15,17,19]. One study used 28mm heads [15], one study used a 26mm head [17] and one study used 28 and 22mm heads [19]. Volumetric wear was not significantly different between the MoP and CoP groups (MD: 33.57mm^3, 95% CI: -215.56-282.70,I^2=98%, p=0.79) (Figure 6). Subgroup analysis was performed on the basis of femoral head size, which included 22mm, 26mm, and 28mm. A 22 mm head size used with a CoP bearing was associated with significantly greater volumetric wear as compared with MoP (MD:-208.81, 95% CI: -351.52—66.10, I^2 = N/A, P=0.004) (Figure 7). No significant difference between MoP and CoP was observed with 26 mm or 28 mm heads.

Discussion

Synthesis of the available randomised controlled trials comparing the revision rates of MoP and CoP THA has been performed. The available evidence shows no significant difference in revision rates, linear or volumetric bearing wear. None of the available studies reported the measurement of metal ion levels.

The National Joint Registry of England, Wales, Northern Ireland and the Isle of Man (NJR) demonstrates a higher revision rate in MoP versus CoP bearings in the most commonly implanted prostheses in the geographical area covered (as seen in table 1 [20]). This difference is observed despite the average age of the CoP cohort being 10 years lower and therefore potentially at higher risk of revision due to higher activity levels and lower mortality rates over the period of observation.

Commonly postulated possible reasons for a lower rate of revision in CoP bearing compared to MoP are a lower rate of bearing wear [21] and a reduced risk of trunnion corrosion [11]. The evidence in this paper contradicts the hypotheses that CoP bearings offer both lower risk of revision or reduced bearing wear than MoP bearings when assessed in randomised controlled trials at a follow up of up to 8 years.

Irrespective of head size, our pooled data shows no statistically significant difference in linear wear between the two bearing combinations, nor a statistically significant difference in volumetric wear for all but the 22mm heads which showed an increase in wear for CoP over MoP.

Data from NJR annual reports suggest that there may be a lower revision rate with CoP compared to MoP bearings [20] but other national joint registries' annual reports do not support this [22-24]. The impact of head size on revision rate is also reported by the major joint registries; a low rate of revision for 32mm heads is reported in the NJR when compared

to other head sizes [1] and a lower rate of revision for 32mm heads compared to those less than 32mm used in all of our included studies was reported by the Australian, New Zealand and Norwegian joint registries [22-24], Data available in national registry reports may be subject to confounding as surgeons and patients have selected one bearing type over the other options available and the bearing has not been randomly allocated as in the studies included in this paper. Registry data can demonstrate association between an intervention and an outcome of interest, whilst the issue of confounding can be tackled through controlling for patient, surgical and healthcare factors in the analysis of such data, there may still be residual confounding for example due to data not collected in the registry. Contemporary analysis of NJR data suggests no difference in the rates of revision for a diagnosis of adverse reaction to metal debris for MoP and CoP THA [25]. This finding is replicated in our study with no significant evidence that CoP bearings offer a better outcome than MoP at short to medium term follow up.

This study has utilised robust, repeatable methods of evidence synthesis to determine if there is any difference in the rate of revision, linear or volumetric bearing wear between MoP and CoP THA. Our study has several limitations, whilst data was available on revision rate and bearing wear, none was available on metal ion levels which we had hoped to use as a surrogate marker of trunnion corrosion. None of the included studies used radiostereometric analysis, recognised as the best tool for detecting the small amounts of polyethylene wear in the early postoperative period [16,26]. The number of patients in the available studies was small and may therefore be underpowered. The available follow up in the published randomised controlled trials is relatively short and may not allow for all revisions due to wear or trunnion corrosion to be captured and reported. Both MoP and CoP bearings exhibit a bedding in and steady phase of wear and so early wear volumes may not

be representative of the wear that can be expected over the lifetime of the implant. The included studies used different types of polyethylene, including non highly cross linked polyethylene [18], different types of ceramic including Zirconia (which, as far as we are aware, is not included in the NJR dataset for example), different types of metal head, different bearing sizes and different implants which may affect the pooling of data performed and may not be generalisable to all patients undergoing THA.

Conclusion

The data from this meta-analysis shows that polyethylene wear rates and survivorship of implants are comparable for MoP and CoP. At this stage data derived from RCTs does not support the additional costs associated with the use of ceramic heads over metal heads in combination with a polyethylene acetabulum. However the follow up in the included studies is short and the types of polyethylene and the zirconia ceramic used in the studies may mean that our meta-analysis is not generalisable to today's practice. High quality evidence in regards to differences in metal ion levels between CoP and MoP is lacking and highlights an area where research should be conducted.

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Figure legends

Figure 1: PRISMA flow diagram of study inclusion

Figure 2: Risk of bias of included studies (Green-low risk, Yellow-unclear risk, Red-high risk)

Figure 3: Odds Ratios of Revision

Figure 4: Linear wear rate per year (mm)

Figure 5: Subgroup analysis by femoral head size of linear wear rate per year (mm)

Figure 6: Volumetric wear rate (mm^3)

Figure 7: Subgroup analysis by femoral head size of volumetric wear rate (mm^3)

Tables

Table 1 NJR Revision Data

				Cumulative percentage probability of revision at -	
Stem/ Cup Brand	**Bearing surface**	**Median Age at pimary**	**Numbers implanted**	**7 years**	**10 years**
Exeter V40/ Contemporary	MoP	74 (69-80)	60,965	1.91 (1.75 - 2.08)	3.21 (2.64 – 3.91)
	CoP	65 (60-70	3,861	1.75 (1.22 – 2.53)	2.62 (1.31 - 5.21)
Exeter V40/ Elite + Ogee	MoP	75 (69-80)	17,747	1.55 (1.32 – 1.82)	2.66 (1.94 – 3.64)
	CoP	65 (59-70)	1,213	1.43 (0.76 – 2.71)	1.43 (0.76 – 2.71)
Corail/ Pinnacle	MoP	71 (65-77)	30.061	2.33 (2.04 - 2.66)	2.58 (2.19 - 3.04)
	CoP	64 (58-70)	8,483	1.84 (1.41 - 2.40)	-

1 Table 2: Study Characteristics

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Reference	Methods	Participants/Hips	Intervention (total) [mean age]	Comparison(s) [mean age]	Outcomes	Duration of follow up (years)	Key Results
Bjorgul, 2013	RCT; Norway	374 patients/397 hips	MoP CoCrMo on polyethylene 28mm (n=127 patients/137 hips)[62.8]	1. MoM metasul 28mm (n=123 patients/129 hips)[63.3] 2. CoP alumina on polyethylene28mm (n=124 patients/131 hips)[63.9]	Harris Hip Score, Abduction Angle, Radiolucency, Revisions	7	- No significant difference in Harris Hip Score between MoP and CoP (p>0.05) - No significant difference in revisions between MoP and CoP (p>0.05)
Ise, 2009	RCT; Japan Linear wear measurement: migration of centre of femoral head in relation to centre of cup using digitised radiographs validated by Tanaka et al Volumetric wear using Hashimoto's equation $\text{Volumetric wear} = r^2h_2 \eth p + 2b + \sin 2b Þ$	80 patients/94 hips	MoP stainless steel on cross linked polyethylene 22mm (n=17 patients/20 hips) [60.9)	1. CoP zirconia (Kyocera) on non cross linked 22mm (n=26 patients/23 hips) [60.0] 2. CoP zirconia (Kyocera) on cross linked 22mm (n=17 patients/25 hips)[61.6] 3. CoP zirconia (Kobelco) on cross linked 22mm (n=20 patients/23 hips)[62.7]	Linear Wear, Volumetric Wear, Direction of Wear	MoP :4.07±0.43 CoP (1): 4.04 ±0.99 CoP (2): 3.80±0.68 CoP (3): 3.73±0.54	- Linear wear rate significantly lower in the CLPE Aeonian sockets of group B (CLPE sockets against Kyocera zirconia heads, 0.067 ± 0.044 mm/y), group C (CLPE sockets against Kobelco zirconia heads, 0.059 ± 0.027 mm/y), and group D (CLPE sockets against stainless steel heads, 0.068 ± 0.039 mm/y) compared with group A (non-CLPE sockets against Kyocera zirconia heads, 0.170 ± 0.098 mm/y).
Kawate, 2009	RCT; Japan Linear wear measurements taken from AP pelvic	60 patients/62 hips	MoP cobalt chromium on highly crossed linked polyethylene 26mm	1. CoP zirconia on highly cross linked polyethylene 26mm (n=31 patients/32 hips)[61.1]	Linear Wear, Volumetric Wear, Revisions	CoP 5 (4.8-5.2) MoP 5 (4.8-5.4)	- No significant difference in both groups in regards to Linear Wear and Volumetric Wear (p>0.05) - No significant difference in revisions between MoP and CoP (p>0.05)

Commented [OG2]: Effect of alumina femoral heads on polyethylene wear in cemented total hip arthroplasty OLD VERSUS CURRENT ALUMINA
K. Tanaka, J. Tamura, K. Kawanabe, M. Shimizu, T. Nakamura
From Kyoto University, Jap
J Bone Joint Surg Br 2003;85:655.

	radiographs using standardized grid films volumetric wear was calculated from the linear wear and the wear direction		(n=29 patients/30 hips)[61.1]				
Kim, 2001	RCT; Korea Linear wear measurement using digitized AP radiographs, volumetric wear calculated using equation $V = \pi\gamma^2\omega$ (V = volumetric wear, γ = radius femoral head, ω = measured linear wear)	70 patients/140 hips	MoP cobalt chrome on hylamer UHMWPE 28mm (n=35 patients/35 hips)[NR]	1. MoP cobalt chrome on hylamer UHMWPE 22mm (35 patients/35 hips)[NR] 2. CoP zirconia on hylamer UHMWPE 28mm (35 patients/35 hips)[NR] 3. CoP zirconia on hylamer UHMWPE 22mm (35 hips)[NR]	Hip Score, Pain Score, Linear Wear, Volumetric Wear, Revisions	6.4 (5-7)	- No significant difference in linear wear or volumetric wear between all groups (p>0.05) - Osteolysis was observed in six patients in both the MoP 28mm group and CoP 28mm group
Kim, 2005	RCT; Korea Linear wear measurement using digitized AP radiographs Volumetric wear measurement tecchnique not described	52 patients/104 hips	MoP cobalt chrome on UHMWPE 28mm (n=52 patients/52 hips)[NR]	1. CoP zirconia on UHMWPE 28mm (52 patients/52 hips)[NR]	Tegner and Lysholm score, Linear Wear, Volumetric Wear, Revisions	7.1 (5-8)	- Linear wear rate was significantly higher in the MoP group in comparison to CoP group (p<0.05) - Volumetric wear rate was significantly higher in the MoP group in comparison to the CoP group (p<0.05) - No significant difference in revisions between MoP and CoP (p>0.05)
Kraay, 2006	RCT; USA Linear wear measurement using digitized radiographs and computer	57 patients/57 hips	MoP CoCrMo on UHMWPE 28mm (n=30 patients/30 hips)[68.9]	1. CoP Zirconia on UHMWPE 28mm (n=27 patients/27 hips)[69.5]	Head Penetration Rate, Harris Hip Score, Revisions	Min 2.0, mean 4.3	- No significant difference in head penetration rate between MoP and CoP (p>0.05) - No significant difference in revisions between MoP and CoP (p>0.05)

Commented [OG3]: Kabo JM, Gebhard JS, Loren G, et al. In vivo wear of polyethylene acetabular components. J Bone Joint Surg **1993;75B:254.**

	assisted vector wear analysis						
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2

Commented [OG4]: J Bone Joint Surg Am. 1997 Nov;79(11):1635-41.
Determination of polyethylene wear in total hip replacements with use of digital radiographs.
Martell JM[1], Berdia S.

Table 3: Reported Revisions

	MoP			CoP		
	# Patients	Hip Type	# Revisions (cause)	# Patients	Hip Type	# Revision (cause)
Kim 2005	52	28 mm	0	52	28 mm	2 (aseptic looseing)
Kawate 2009	29	26 mm	0	31	26 mm	0
Bjorgul 2013	127	28 mm	3 (2-dislocation; 1-infection)	124	28 mm	1 (infection)
Kraay 2006	30	28 mm	0	27	28 mm	0
Kim 2001	35	28 mm	6 (osteolysis)	35	28 mm	6 (osteolysis)

Appendices

Appendix 1: Search strategies

MEDLINE Search Strategy

1 exp Arthroplasty, Replacement, Hip/ (16882)
2 (arthoplast$ adj2 (hip or femur or femoral)).mp. (47)
3 exp hip joint/ (21240)
4 (hip adj2 joint).mp. (26719)
5 head neck interface.mp. (7)
6 ((head adj2 neck) and hip).mp. (1022)
7 exp Hip Prosthesis/ (18641)
8 (hip adj2 replace$).mp. (22678)
9 ((modular or taper) adj2 interface).mp. (52)
10 trun?ion.mp. (65)
11 or/1-10 (51745)
12 exp prosthesis failure/ (21432)
13 (prosthes?s adj2 fail$).mp. (21705)
14 Implant Capsular Contracture.mp. (113)
15 ae.fs. [adverse effect as a subheading] (1351511)

16 adverse reaction to metal debris.mp. (29)
17 armd.ti. (50)
18 exp Corrosion/ (3866)
19 (corrosion adj2 fret$).mp. (92)
20 metalosis.mp. (8)
21 exp Equipment Failure Analysis/ (30495)
22 failure analys?s.mp. (31021)
23 11 and (or/12-22) (16000)
24 exp aluminum oxide/ (15814)
25 aluminum oxide.mp. (6542)
26 exp ceramics/ (16800)
27 ceramic$.mp. (21311)
28 porcelain.mp. (10536)
29 ceramic on ceramic.mp. (330)
30 or/24-29 [Ceramic including ceramic on ceramic] (40636)
31 exp Chromium Alloys/ (3801)
32 (cobalt adj2 chrome).ti,ab. (597)
33 metal on metal.mp. (1441)
34 exp metals/ (860651)
35 metal.ti,ab. (167209)
36 exp titanium/ (25137)
37 titanium.mp. (37180)
38 or/31-37 [all metal including metal on metal] (963291)
39 exp Polyethylenes/ (13176)
40 poly.ti,ab. (109237)
41 Polyethylene.mp. (66587)
42 or/39-41 (172120)
43 23 and 30 and 38 [ceramic verus metal] (486)
44 23 and 30 and 38 and 42 [ceramic, metal and poly] (315)
45 23 and 30 and 42 [ceramic and poly] (395)
46 23 and 38 and 42 [metal and poly] (1026)
47 or/43-46 (1277)
48 remove duplicates from 47 (1263)
49 limit 48 to animals (54)
50 48 not 49 (1209)
51 limit 50 to english language (1064)

EMBASE Search Strategy

1 arthroplasty, Replacement, Hip.mp. (106)
2 exp hip arthroplasty/ (13307)
3 ((arthoplast$ or replace$) adj2 (hip or femur or femoral)).mp. (13707)
4 hip joint/ (42414)
5 head neck interface.mp. (7)

1	6	((head adj2 neck) and hip).mp. (1491)
2	7	exp Hip Prosthesis/ (31493)
3	8	((modular or taper) adj2 interface).mp. (58)
4	9	trun?ion.mp. (82)
5	10	or/1-9 (82016)
6	11	exp prosthesis failure/ (25873)
7	12	(prosthes?s adj2 fail$).mp. (14740)
8	13	Implant Capsular Contracture.mp. (183)
9	14	ae.fs. [adverse events as a subheading] (1090809)
10	15	adverse reaction to metal debris.mp. (32)
11	16	armd.ti. (62)
12	17	Corrosion/ (7380)
13	18	(corrosion adj2 fret$).mp. (100)
14	19	metalosis.mp. (15)
15	20	exp Equipment Failure Analysis/ (3508)
16	21	failure analys?s.mp. (1379)
17	22	10 and (or/11-21) (12541)
18	23	exp aluminum oxide/ (11317)
19	24	aluminum oxide.mp. (11921)
20	25	exp ceramics/ (13012)
21	26	ceramic.mp. (17755)
22	27	porcelain.mp. (5923)
23	28	ceramic on ceramic.mp. (397)
24	29	or/23-28 [Ceramic including ceramic on ceramic] (35396)
25	30	22 and 29 (742)
26	31	exp titanium/ (29737)
27	32	exp chromium/ (33435)
28	33	exp chromium derivative/ (4805)
29	34	exp cobalt/ (37588)
30	35	chrome.mp. (2990)
31	36	titanium.mp. (49870)
32	37	22 and (or/31-36) (1164)
33	38	30 and 37 (217)
34	39	exp polyethylene derivative/ or exp polyethylene/ (18037)
35	40	Polyethylene.mp. (50144)
36	41	poly.ti,ab. (120660)
37	42	or/39-41 (167628)
38	43	37 and 42 (454)
39	44	30 and 42 (424)
40	45	38 or 43 or 44 (791)
41	46	remove duplicates from 45 (787)
42	47	limit 46 to animal studies (13)
43	48	46 not 47 (774)

49 limit 48 to english language (709)

COCHRANE Search Strategy

1 hip arthroplasty.mp. (1462)
2 ((head adj2 neck) and hip).mp. (39)
3 (hip adj2 joint).mp. (1164)
4 hip prosthesis.mp. (1343)
5 trun?ion.mp. (1)
6 1 or 2 or 3 or 4 or 5 (3124)
7 ceramic.mp. (643)
8 6 and 7 (69)
9 (titanium or chrome or cobalt).mp. [mp=ti, ot, ab, tx, kw, ct, sh, hw] (1500)
10 6 and 9 (119)
11 polyethylene.mp. [mp=ti, ot, ab, tx, kw, ct, sh, hw] (2867)
12 6 and 11 (186)
13 8 and 10 (23)
14 6 and 7 and 11 (51)
15 9 and 11 (85)
16 8 and 11 (51)
17 13 or 14 or 15 or 16 (119)
18 remove duplicates from 17 (117)
19 limit 18 to english language [Limit not valid in CDSR,ACP Journal Club,DARE,CLCMR;

1 Appendix 2: PRISMA and MOOSE Checklists

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	3
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	4
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	6
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	8/9
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	-
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	8/9
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	8/9
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	27-30
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	8/9/11
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	8/9/11
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	8/9
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	9

Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	9/10
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	10

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	12
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	12/13
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	figures
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	figures
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	figures
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	figures
Synthesis of results	21	Present the main results of the review. If meta-analyses are done, include for each, confidence intervals and measures of consistency.	11-13
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	21
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	12/13
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	14-16
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	15
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	15/16
FUNDING			

Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	n/a

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

MOOSE (Meta-analyses Of Observational Studies in Epidemiology) Checklist

A reporting checklist for Authors, Editors, and Reviewers of Meta-analyses of Observational Studies. You must report the page number in your manuscript where you consider each of the items listed in this checklist. If you have not included this information, either revise your manuscript accordingly before submitting or note N/A.

Reporting Criteria	Reported (Yes/No)	Reported on Page No.
Reporting of Background		
Problem definition	Yes	6
Hypothesis statement	Yes	7/8
Description of Study Outcome(s)	Yes	10/11
Type of exposure or intervention used	Yes	12
Type of study design used	Yes	12
Study population	Yes	25
Reporting of Search Strategy		
Qualifications of searchers (eg, librarians and investigators)	Yes	9
Search strategy, including time period included in the synthesis and keywords	Yes	9
Effort to include all available studies, including contact with authors	Yes	9/10
Databases and registries searched	Yes	9
Search software used, name and version, including special features used (eg, explosion)	Yes	9
Use of hand searching (eg, reference lists of obtained articles)	Yes	9
List of citations located and those excluded, including justification	Yes	figures
Method for addressing articles published in languages other than English	Yes	9
Method of handling abstracts and unpublished studies	Yes	9
Description of any contact with authors	No	n/a
Reporting of Methods		
Description of relevance or appropriateness of studies assembled for assessing the hypothesis to be tested	Yes	12-13
Rationale for the selection and coding of data (eg, sound clinical principles or convenience)	Yes	10
Documentation of how data were classified and coded (eg, multiple raters, blinding, and interrater reliability)	Yes	10
Assessment of confounding (eg, comparability of cases and controls in studies where appropriate	No	n/a

Reporting Criteria	Reported (Yes/No)	Reported on Page No.
Assessment of study quality, including blinding of quality assessors; stratification or regression on possible predictors of study results	Yes	10
Assessment of heterogeneity	Yes	11
Description of statistical methods (eg, complete description of fixed or random effects models, justification of whether the chosen models account for predictors of study results, dose-response models, or cumulative meta-analysis) in sufficient detail to be replicated		
Provision of appropriate tables and graphics	Yes	figures
Reporting of Results		
Table giving descriptive information for each study included	yes	25-26
Results of sensitivity testing (eg, subgroup analysis)	yes	13/14/figures
Indication of statistical uncertainty of findings	Yes	13/14
Reporting of Discussion		
Quantitative assessment of bias (eg, publication bias)	Yes	22
Justification for exclusion (eg, exclusion of non–English-language citations)	Yes	9/20
Assessment of quality of included studies	Yes	9/12/13
Reporting of Conclusions		
Consideration of alternative explanations for observed results	Yes	16
Generalization of the conclusions (ie, appropriate for the data presented and within the domain of the literature review)	Yes	16/17
Guidelines for future research	No	n/a
Disclosure of funding source	No	n/a